66 Extension Note

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Policy Implications of an Assessment of Long-term Risks to Marbled Murrelet Populations in British Columbia

J. Douglas Steventon, MSc, R.P.Bio
Ministry of Forests
Research Program
Email:
Doug.Steventon@gems3.gov.bc.ca

Glenn D. Sutherland, PhD, R.P.Bio
Cortex Consultants Inc.
Email: gsutherland@cortex.ca

and

Peter Arcese, PhD
University of British Columbia
Email: arcese@interchange.ubc.ca

The Marbled Murrelet (*Brachyramphus marmoratus*), a small seabird that nests in old forests of coastal British Columbia, is of international conservation concern. Beginning in 2001 the Canadian Marbled Murrelet Recovery Team (CMMRT) undertook a three-part conservation assessment for the species. The assessment will form the basis of a revised national Marbled Murrelet Recovery Strategy and inform revisions to the provincial Identified Wildlife Management Strategy and land-use planning initiatives.

This note summarizes the risk assessment component (Part C; Steventon et al. 2003) of the conservation assessment. Our goal was to assess the effects of alternative broad-scale forest management objectives (amounts, types, and sizes of coastal forest stands) on the relative probability of persistence of regional and coast-wide murrelet populations.

We used habitat-based population viability analysis (PVA) in this assessment. Population viability analysis is a well known science-based means of projecting the cumulative effects of all the factors that affect populations, including uncertainty. Methods and results, described in detail by Steventon et al. (2003), were peer reviewed by three independent scientists.

Status and Biology of the Marbled Murrelet

Marbled Murrelets are listed as "threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and are included on the B.C. Conservation Data Centre[1] Red List and in the province's Identified Wildlife Management Strategy.[2] The species is also listed as "threatened" in the U.S. Pacific Northwest. While Marbled Murrelets remain relatively common on the British Columbia coast, there is concern about ongoing declines in nesting habitat and, by extension, risk to regional populations.

Factors limiting Marbled Murrelet populations are not well understood (CMMRT 2003). Data from British Columbia suggest that population size is likely declining and sensitive to changes in adult survival, juvenile survival, and fecundity (Burger 2002). Outside the nesting period, murrelets spend their life in estuaries or on the open ocean. How the marine environ-

1 B.C. Ministry of Sustainable Resource Management, Victoria, B.C.
2 B.C. Ministry of Water, Land and Air Protection, Victoria, B.C.

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ment influences their population is poorly documented, but climate change (e.g., resulting in altered food availability), marine habitat degradation (e.g., pollution) and direct human-induced mortality (e.g., fisheries by-catch) potentially have negative effects on murrelets.

The prevailing view is that the most serious long-term threat to Marbled Murrelet populations in British Columbia is the continued loss of nesting habitat (CMMRT 2003)—old-growth forest within 50 km of the coastline. Timber harvesting appears to affect murrelet populations by reducing the availability of nest trees and possibly reducing survival due to edge effects (Burger 2002).

Characterizing Risks to Murrelets

The general question we examined is: How is the resilience of Marbled Murrelet populations in British Columbia affected by further removal of nesting habitat, given the many uncertainties about murrelet biology and future environmental conditions?

To find the answer, we used multiple computer projections of possible future population size. We applied a variety of policy scenarios and a range of biological assumptions. Policy scenarios represented varying amount and quality (nesting density) of nesting habitat, rates of habitat decline, and amount of forest edge.

For each scenario, the range of values we applied represented uncertainties in murrelet population biology and other factors. Thus, although we cannot predict with certainty the outcome for any given policy scenario, we report the "expected" value of persistence (the proportion of projected populations that lasted 100 years or longer for all combinations of input values). An increase in expected probability of persistence indicates greater resilience in the face of uncertainty, and therefore lower risk of future loss of the population. A more resilient habitat scenario means that the population can better absorb at-sea survival fluctuations and uncertainty about habitat relationships.

Important to note is that the influence of factors not associated with nesting, such as mortality at sea and variations in fecundity associated with food availability, result in the risk always exceeding zero regardless of the amount and quality of nesting habitat retained.

Our analyses focused on the six Conservation Regions identified by the CMMRT (Figure 1), as well as on the coast-wide scale. We used the current range of population estimates made by the CMMRT (Table 1) to guide our assessment.

Assessment Questions

Q1: How are the amount and quality of nesting habitat, and the resultant nesting capacity, related to long-term persistence of murrelets?

We found that the amount and quality (expressed as nesting density) of nesting habitat are key factors affecting persistence estimates. Figure 2 displays the trade-off between the density of nesting Marbled Murrelets (an index of the quality of their nesting habitat) and the amount of that habitat, in terms of the probability that populations will persist for at least 100 years. Forest management can affect both the amount and quality of habitat.

To interpret Figure 2, consider as an example the change in risk if the density of murrelets is held constant at 0.006 nests per hectare. With 100 000 ha of habitat of this quality, our assessment forecasts a likelihood of 50–60% that murrelet populations would persist for 100 years. If 175 000 ha,

FIGURE 1 *Conservation Regions defined for the Marbled Murrelet in British Columbia. Source: CMMRT (2003).*

250 000 ha, or 400 000 ha of habitat of this same quality were available, the likelihood of persistence for 100 years would rise to 60–70%, 70–80%, and 80–90%, respectively. Above 400 000 ha of habitat of this quality, our assessment predicts no further substantive increase in likelihood of persistence unless the quality of the habitat (nesting density) also increases.

We found that to achieve >80% expected probability of persistence in a region required >2000 nesting pairs, while >90% required >5500 nesting pairs.

Not all old growth is considered equally suitable for nesting by Marbled Murrelets, but scientific debate continues about the suitability of forest types. The Recovery Team has defined general attributes of "most," "moderately," and "least preferred" habitats (CMMRT 2003). Explicit assessment of risk associated with specific land management plans, however, requires assigning estimates of nesting density to mapped areas of available habitats (e.g., Steventon 2003).

TABLE 1 *Estimates of Marbled Murrelet population size in 2002 for British Columbia's six Conservation Regions (CMMRT 2003). The low precision of historic censuses results in a range of "optimistic" to "pessimistic" estimates.*

	2002 population estimate	
Conservation Region	**Optimistic**	**Pessimistic**
Northern Mainland Coast	14 700	10 100
Haida Gwaii (Queen Charlotte Islands)	9 500	8 500
Central Mainland Coast	21 000	10 000
Southern Mainland Coast	7 000	6 000
West and North Vancouver Island	24 500	19 400
East Vancouver Island	1 000	700
Total British Columbia	77 700	54 700

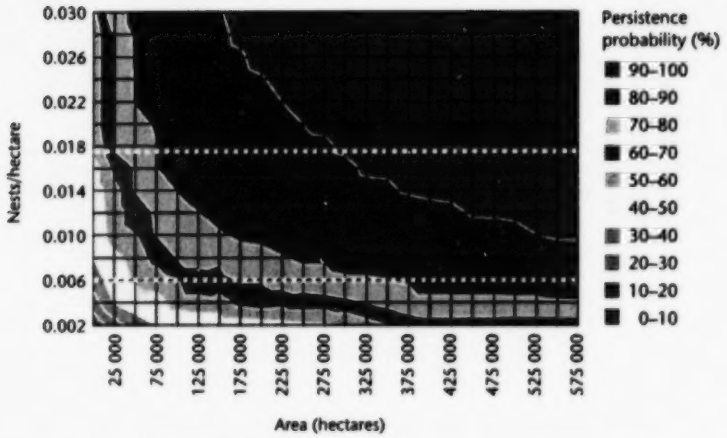

FIGURE 2 *Expected probability of population persistence (≥100 years) as a function of amount and quality of nesting habitat (all patch sizes weighted equally). The dashed white lines represent the range of mean density estimates inferred from recent British Columbia studies (Burger 2002.).*

Q2: How important are patch size objectives?

Smaller patches have proportionally more area affected by edge than do larger patches (greater perimeter-to-edge ratio). When we modelled the prevailing CMMRT opinion that nesting within 50 m of forest edges probably increases nest predation rate, we found that plausible landscape shifts towards smaller patch sizes had a small negative effect on persistence. Thus, measures to reduce management-induced edge are advisable, but the primary focus of habitat plans should be on amount and quality (potential nesting density) of nesting habitat.

Q3: What are the risks of population loss given present levels of nesting habitat?

The coast-wide risk to the persistence of Marbled Murrelets is low, given current estimated population sizes and amounts of nesting habitat. However, the East Vancouver Island region (Figure 1) likely depends on immigration and the restoration of nesting habitat to remain viable (Table 2).

Q4: What are the risks of using the minimum criteria of the CMMRT and International Union for the Conservation of Nature (IUCN)?

We applied the Recovery Team recommendation that current population sizes not be reduced by more than ~30% (CMMRT 2003). We also estimated the risks of eventual 50% and 65% reductions in nesting population size, which could be allowable under IUCN/COSEWIC rules while still avoiding the "vulnerable" listing (≤1%/year over each 30-year period).

Applying the Recovery Team criteria resulted in individual Conservation Regions varying from a potential low of 38% expected probability of persistence for East Vancouver Island to 92% probability with optimistic population assumptions for West and North Vancouver Island (Table 2). Coast-wide, the Recovery Team objectives resulted in 94–99% expected probability of persistence.

TABLE 2 *Expected probability of population persistence (≥100 years) by region for: current CMMRT population estimates; recommended CMMRT 2032 population thresholds; and after 50% and 65% declines in current population size. Ranges of probabilities within table cells are based on pessimistic and optimistic assumptions of current population size and the strength of environmental correlations among regions.*

Conservation Region	Present thresholds[a]	CMMRT decline	50% decline	65% decline
Northern Mainland Coast	84–89	80–84	71–81	64–71
Haida Gwaii (Queen Charlotte Islands)	83–84	77–79	70–71	62–64
Central Mainland Coast	84–91	80–88	71–84	64–78
Southern Mainland Coast	78–80	65–78	64–64	55–56
West and North Vancouver Island	90–92	87–90	84–86	80–83
East Vancouver Island	38–41	38–40	20–25	15–20
Total British Columbia	95–99[b]	94–99	92–99	90–99

a For 2032; these are minimum population objectives by region (see CMMRT 2003).
b Range represents pessimistic and optimistic population estimates, and uncertainty of correlation among regions.

Thresholds based on the IUCN/COSEWIC acceptable rates of decline (e.g., populations allowed to decline to 50–65% of current size over 60–90 years) were somewhat less likely than the CMMRT thresholds to achieve coast-wide persistence (Table 2).

Risks to individual regions, especially East Vancouver Island, the Southern Mainland Coast, and Haida Gwaii (Figure 1) increased markedly when the IUCN/COSEWIC thresholds were used.

Q5: How sensitive are estimates of risk to the time horizon of assessment?

As it may take up to 300 years for nesting habitat to recover after harvest, assessment time horizons longer than 100 years (the IUCN/COSEWIC criterion time horizon) may be appropriate. Nonetheless, we found that simulations providing an expected persistence probability of 95% or greater at 100 years also maintained high expected persistence probability at 300 years. After accounting for uncertainties, a 95% probability at 100 years was found to be impossible at the regional scale, but achievable coast-wide.

Q6: What is an acceptable level of risk?

Acceptable level of risk depends on the nature of the risk (e.g., its reversibility and the severity of the outcome), the tolerance of risk by decision-makers, the spatial scale under assessment (region vs. coast-wide), and the incremental costs of reducing risk.

One of the criteria used by the International Union for the Conservation of Nature (IUCN 2001) to classify species as "vulnerable" ("threatened" in the COSEWIC system) is whether they are likely to experience >10% risk of extinction in the next 100 years. This classification implies that a level of risk commensurate with 90% or better odds of persistence will avoid a species being listed as "vulnerable" (although other criteria such as fragmented population or small total population size may apply). Our analysis found, given present uncertainty, that a high likelihood of achieving this particular IUCN stan-

dard (or better) is feasible coast-wide, but will be difficult to achieve at the regional scale.

Conclusions and Recommendations

The choice of an acceptable level of risk is subjective, and in this analysis is strongly affected by the spatial scale of application (i.e., region vs. coast-wide). We found that risk to persistence within a Conservation Region was strongly reduced by maintaining habitat sufficient for ~2000 nesting pairs (80% expected confidence of persistence). Increasing probability of persistence above 80% required an exponential increase in nesting capacity (e.g., 5500 pairs per region for 90% persistence).

By applying the range of mean densities reported in British Columbia, we estimate that 2000 nesting pairs would require 100 000–400 000 ha of old growth per Marbled Murrelet Conservation Region. Coast-wide this would equal 600 000–2.4 million ha, providing a 90–99% expected confidence of persistence at the coast-wide scale. Achieving 5500 nesting pairs per region would require 250 000–1 million ha of old growth per region, with little reduction in coast-wide risk, but an increase in confidence of persistence at the regional level (see Question 1, above). Applying the IUCN 90% persistence standard to all individual regions is likely impossible because it requires an area of old-growth habitat larger than the total size of some of the individual regions. However, this standard appears achievable at the coast-wide scale.

Because 95% expected persistence probability provided much greater assurance of persistence at time scales greater than 100 years, we recommend applying 95% at the coast-wide scale. Within and among the regions, we recommend examining the costs of incremental improvement in risk reduction.

The CMMRT population and habitat recommendations will likely maintain a high probability of persistence at the coast-wide scale (≥94% at 100 years). At the scale of individual regions, the probabilities of persistence of current populations are somewhat lower (especially for East Vancouver Island), but declines in these probabilities are ≤5% for the CMMRT thresholds except for the Southern Mainland Coast (12–13%). Further reductions to 50% or 65% of present habitat capacity would likely maintain a high probability of persistence coast-wide, but significantly decrease the probability for some individual regions.

It may make sense in the context of meeting other socio-economic objectives to consider trading off increased risk in some regions for decreased risk in others, while achieving a high confidence of persistence coast-wide. It is important for policy-makers to understand that this approach involves accepting higher levels of risk in some regions.

Estimates of population persistence and size were only modestly affected by the details of patch shape and size (habitat configuration). While reducing habitat fragmentation is prudent, our results suggest that this factor is much less important than the amount and quality (nesting density) of habitat retained.

Results were highly sensitive to uncertainty of demographic rate assumptions and future at-sea conditions. The risk from this uncertainty can be partly offset by retaining a greater amount of nesting habitat. Our persistence estimates included a substantial buffer of habitat to account for that uncertainty.

Future research aimed at improving estimates of nesting density and habitat selection would substantially

help reduce uncertainty about the persistence of murrelet populations. Radio-tagging and watershed-level radar surveys could also provide greater information about the range of demographic variability and population synchrony among regions. As well, monitoring population trends by region and assessing the relative effect of at-sea conditions vs. on-shore influences on populations will be essential in helping prioritize conservation efforts in the future.

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